EXECUTIVE SUMMARY

CarbonCure Technologies ready mix concrete system mineralizes waste carbon dioxide into ready mix concrete to improve the compressive strength and reduce the environmental footprint of concrete during the manufacturing process. This system can be easily integrated into any ready mix concrete facility with no disruption to ordinary production. Concrete producers can use the CarbonCure system to improve their concrete products in any ready mix concrete application without compromising on mix batching time or fresh properties.
THE CARBONCURE TECHNOLOGIES READY MIX CONCRETE SYSTEM

The CarbonCure Technologies (CCT) ready mix system consists of four main components:

1. Valve enclosure
2. Control Enclosure
3. Injection nozzle
4. Telemetry

The valve enclosure houses the piping configuration of the CCT ready mix system and is connected directly to the carbon dioxide (CO$_2$) supply tank. Solenoid valves permit the flow of both gas and liquid CO$_2$, while pressure and temperature sensors are used to meter the flow as it leaves the system. The system is supplied with both gas and liquid CO$_2$. The gas is used to pressurize the system prior to liquid injection, and to purge the piping configuration and discharge hose of liquid CO$_2$ at the end of each injection. Once liquid CO$_2$ leaves the CCT system it changes phase to become a mixture of gas and solid due to a significant drop in pressure. While liquid CO$_2$ is metered by the CCT ready mix system, it is solid CO$_2$ (e.g. snow or dry ice) that comes into contact with the concrete during batching. A valve enclosure as installed at an existing customer’s ready mix plant is presented in Figure 1.

The control enclosure is the interface between the CCT system and the batcher, allowing the batcher to view the system during operation, navigate through existing alarms, and adjust system settings. The control enclosure is mounted in the batch house of ready mix concrete plants and communicates with the customer’s batching system to seamlessly integrate with normal batching operations. Figure 2 shows the control enclosure mounted inside a customer’s batch office.

The injection nozzle location varies depending on concrete batching format. In the case of a central mixer, a fixed injection nozzle is installed at the loading end of the mixer so that CO$_2$ is injected directly into the mixing concrete. In the case of a dry-batch operation, a fixed injection nozzle is positioned in the loading boot adjacent to the cement pipe to inject CO$_2$ directly into the ready mix truck. Figure 3 shows installed locations of the injection nozzle at existing CarbonCure customer locations for a central mixer plant (left) and dry batch plant (right). Typically, a rubber extension is installed on the injection nozzle to reduce build up and increase the nozzle length.
The telemetry system allows CarbonCure staff to monitor installed ready mix systems to diagnose issues in real time. CCT staff gather and analyze sensor data to ensure the system is operating properly and can address problems before they impact the production of the ready mix plant. The telemetry gathers system usage data (e.g. how much CO₂ has been used by the ready mix producer) that can be used by the customer to determine the environmental benefit of their concrete products associated with the use of the CarbonCure ready mix system. The telemetry system is housed in the control enclosure.

INTEGRATION AND INSTALLATION REQUIREMENTS

The first step in the installation process is to source a supply of CO₂ by contacting local industrial gas suppliers. The gas supplier can assist in the selection of gas hardware as it depends upon the customer’s monthly concrete production and CO₂ demand. Typically a micro-bulk, mini bulk or bulk tank can meet the needs of a CarbonCure customer. Bulk tank installations require a concrete pad to support the tank, while the smaller micro-bulk tanks offer a versatile solution for quicker installations.

Once the CO₂ tank is installed at the customer’s site, the valve enclosure is mounted in close vicinity to the tank and the control enclosure is mounted in the batch house. A multi-conductor control cable is run between the control and valve enclosures to allow communication between the two. Steel braided, smooth bore transfer hoses are installed to supply the valve enclosure with both gas and liquid CO₂, and a discharge hose delivers the metered CO₂ from the valve enclosure to the injection nozzle. The discharge hose is insulated and covered with foil tape to reduce heat transfer.

The CarbonCure ready mix system integrates with the customer's batching system in the same manner as other admixtures. The CCT system acts as a direct feed admixture and doses CO₂ in real-time once approximately 50% of the cement content has entered the central mixer or ready mix truck. Other integration options are possible if the installation requires load cell or bottle feed admixture integration.
The recommended integration and installation procedure for producers is as follows:

1. Contact a local supplier to arrange a CO₂ supply and tank installation.
2. If a bulk tank is selected, pour a concrete pad that meets specifications and dimensions provided by the CO₂ supplier as close to the truck loading area as possible.
3. Have CO₂ supplier deliver and set tank on level surface/concrete pad.
4. Receive CCT equipment in shipping crate (Figure 4).

5. Mount the valve enclosure within 10' of the CO₂ tank and mount the control enclosure in the batch office. Provide power to each enclosure. The control enclosure should be powered from the same source as the customer batch panel.
6. Run the control cable between the valve enclosure and the control enclosure.
7. Identify an open input and output card in the admixture panel for integration into the existing batching system. Identify an open window on the manual station.
8. Supply two 18 gauge wires from the admixture panel to the control enclosure. One is used to initiate the system (feed) and the other is to receive pulses from the CCT system.
9. Run both transfer hoses from the CO₂ supply to the valve enclosure. Insulate the liquid CO₂ hose.
10. Run and insulate the discharge hose from the valve enclosure to the injection location.
11. Mount the injection nozzle on the loading end of the central mixer in central batch applications or inside loading boot for dry-batch applications. CarbonCure staff will give guidance on where to mount the nozzle while on-site.
12. Integrate CO₂ into the customer batching system and adjust batching sequence as required.

After the ready mix system has been installed, commissioning trials are required to determine the optimum dosage of CO₂ for selected mix designs. With the help of the Technical Services and Support (TSS) team at CCT, customers typically select their highest volume residential and light commercial mixes to test with the addition of CO₂, comparing control samples to a range of CO₂ dosages to find which dose delivers optimum results. The optimum dose is dependent on both the materials and apparatus of injection. The dosage ramp testing requires several data points at each dose (6 - 12 tests per dose) as well as control data for comparison (historical data is valuable). Once the optimum dose has been identified, a cementitious reduction is recommended while the customer continues to collect production data on the adjusted mix design. The TSS team will work with the customer to determine the appropriate cementitious reduction based on trial results and will assist with testing and analysis as required.
**THE SCIENCE**

To understand the chemical reaction between cement and CO$_2$, it helps to first understand the cement production process. Cement is produced by mining limestone from a quarry, transporting it to a cement manufacturing plant, and heating it to high temperatures in a kiln. However, during this process a chemical reaction called calcination takes place – the high heat breaks down the limestone (CaCO$_3$) and drives off CO$_2$ which is then introduced into the atmosphere as emissions. Including carbon emissions from fuel combustion, the cement manufacturing produces between 800 to 1000 kg of CO$_2$ per tonne of cement produced.

CarbonCure concrete is created using a process called CO$_2$ Utilization (Figure 5). While concrete carbonation concerns the reaction of mature cement matrices with atmospheric carbon dioxide, CO$_2$ utilization involve the purposeful reaction of carbon dioxide with hydrating cement. When CO$_2$ is injected into the concrete mix, it reacts with calcium in the cement and to form solid calcium carbonate. These nano-sized calcium carbonate minerals become embedded throughout the entire concrete mix and catalyze cement hydration.

**SUMMARY**

The CarbonCure Technologies ready mix system is simple to integrate into an existing concrete plant and allows the producer to inject carbon dioxide into their concrete products. The retrofit process can be done without disruption to regular production. Carbon dioxide injections are integrated into the batching and mixing process, much like admixtures, and do not impact regular production cycle times or fresh properties. With the use of CarbonCure Technologies ready mix systems, producers can create a concrete product that has the desired performance characteristics but with a reduced environmental impact.